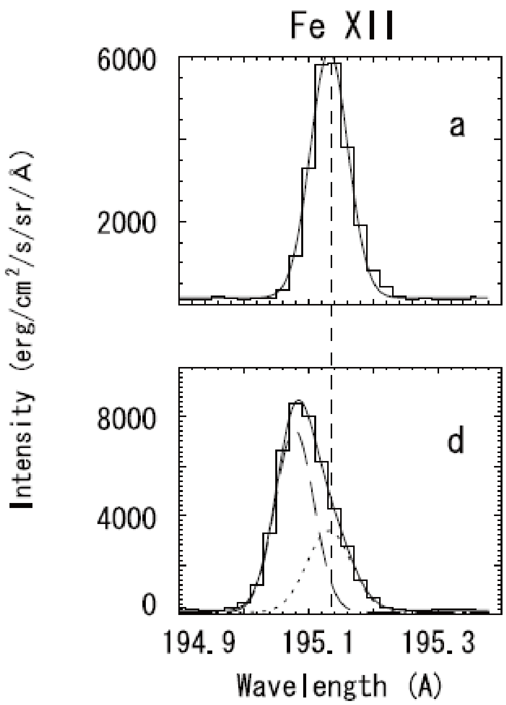
# Using the Doppler Shift to Study Gas




The Hinode Extreme Ultraviolet Imaging Spectrometer (EIS) sorts the light from the sun into a spectrum. When atoms are heated, they produce specific wavelengths of light, called spectral lines.

When a fire truck races towards you, the siren sounds at a higher pitch than when it races away. This is called the Doppler Shift, and it can be precisely used to measure the speed of a gas cloud that is emitting energy at a precise wavelength.

By measuring the Doppler Shift of the FeXII line, solar physicists can determine how fast the plasma was moving on the sun, even though they cannot see any features in the images that show this movement in a series of time-lapse photographs. Here's how they do it!

The figure to the left shows the intensity of the light produced by an iron atom that has lost 11 of its electrons. The top panel shows the light produces by a cloud that was at rest near the solar surface. The bottom panel shows a similar plasma cloud that was in motion during an X-class solar flare, which occurred on December 13, 2006. The plots were published by Dr. Shinsuke Imada and his co-investigators in the *Publications of the Astronomical Society of Japan* (v. 59, pp. 759).

Problem 1 - To the nearest one-hundredth of an Angstrom, what is the wavelength of the FeXII emission line for: A) the gas at rest: $\lambda$(rest)? B) the gas in motion: $\lambda$(moving)?

Problem 2 - The Doppler Formula relates the amount of wavelength shift to the speed of the gas according to

$$V = 300{,}000 \text{ km/sec} \times \frac{\lambda\text{ (rest)} - \lambda\text{(moving)}}{\lambda\text{ (rest)}}$$

From the information in the two panels, what was the speed of the plasma during the solar flare event?

Problem 3 - From the location of the peak of the moving gas, is the gas moving towards the observer (shifted to shorter wavelengths), or away from the observer (shifted to longer wavelengths)?

Problem 4 - From your answer to Problem 3, during a flare, is the heated plasma flowing upwards from the solar surface, or downwards to the solar surface? Explain your answer by using a diagram.

## Answer Key:

**Problem 1** - To the nearest one-hundredth of an Angstrom, what is the wavelength of the FeXII emission line for: A) the gas at rest: $\lambda$(rest)? B) the gas in motion: $\lambda$(moving)?

Answer: Using a millimeter ruler, the wavelength scale between 194.9 Angstroms and 195.1 Angstroms is 17 millimeters, so the scale of the spectrum is 0.2 Angstroms/17 mm = 0.01 Angstroms per millimeter, so A) the peak of the curve in Panel A is at 195.1 + 0.01 x 3 mm = 195.13 angstroms. B) The peak in Panel D is at 195.1 - 0.01x1mm = 195.09 Angstroms.

**Problem 2** - The Doppler Formula relates the amount of shift to the speed of the gas according to

$$V = 300{,}000 \text{ km/sec} \times \frac{\lambda(\text{rest}) - \lambda(\text{moving})}{\lambda(\text{rest})}$$

From the information in the two panels, what was the speed of the plasma during the solar flare event?

Answer: $\lambda$ (rest) = 195.13 Angstroms, $\lambda$(moving) = 195.09 Angstroms. So

V = 300,000 x ( 195.13 - 195.09)/195.13

= 61 kilometers/sec

**Problem 3** - From the location of the peak of the moving gas, is the gas moving towards the observer (shifted to shorter wavelengths), or away from the observer (shifted to longer wavelengths)?
Answer: The peak in panel B is shifted towards smaller, shorter, wavelengths so the gas is 'blue-shifted' and moving away from the observer.

**Problem 4** - From your answer to Problem 3, during a flare, is the heated plasma flowing upwards from the solar surface, or downwards to the solar surface? Explain your answer by using a diagram.
Answer: The FeXII measurement showed plasma flowing towards the observer. Because the gas was located between the solar surface and the observer, it must have been flowing upwards from the surface.